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ABSTRACT

This paper uses interviews with six female doctoral students in one mathematics department to look at the opportunities these women had to interact with faculty and to begin to understand the relationships between female doctoral students and faculty as the students learn to become mathematicians. In this department, the student attrition rate is more than 50%. The interviews were open conversations designed to elicit subjective and personal aspects of students' experiences. The six women described relationships with their professors that might be characterized as "benign neglect," in which there was little interaction in or out of class. The underlying process of these interactions can be conceptualized using the model of legitimate peripheral participation (J. Lave and E. Wenger, 1991), and it also may be regarded within the model of education based on the notion of caring proposed by N. Noddings (1992). The lack of care apparent to these students contributed to the departure from the program of two of the interviewed students, while an overt act of care on the part of a faculty member caused two others who had been thinking of leaving to continue. An appendix contains the interview outlines. (Contains 30 references.) (SLD)

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ED 466 633

Talking the Talk:

Graduate Women in the Disciplinary Culture of Mathematics

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While girls and boys take similar amounts of mathematics in high school (National Center for Education Statistics, 1997), participation of females in mathematics decreases as they progress to higher educational and professional levels. In 1994, women received 47% of bachelor's degree awarded in mathematics in the U.S.. Following this cohort of women into graduate school and beyond, we find that also in 1994, women comprised 35% of the full-time graduate students enrolled for the first time in mathematics. In 1996, women received 40% of masters degrees in mathematics, and in 1999-2000, they received 27% of doctoral degrees. (National Science Foundation, 2000). In the fall of 2000, 22% of full-time faculty and 38% of part-time mathematics faculty at U.S. institutions were female (Loftsgarden, Maxwell, & Priestly, 2001a).

Although the attrition rates from graduate school in mathematics are estimated at anywhere between 30% and 70%, (Bowen & Rudenstine, 1992; Cooper, 2000; Golde, 1996; National Research Council, 1992; Zwick, 1991) little data are available concerning whether women leave graduate school in mathematics without degrees at a different rate from men. Bowen and Rudenstine (1992) provide data from 10 institutions that indicate that the gender gap in completion rates[1] for mathematics doctorates closed in the 1970s, although women continued to have longer average time to degree. In the cohort of women described above, we cannot know if the relatively high percentage of women receiving master's degrees represent students who entered graduate school with the intention of receiving the masters, or if they represent attrition from doctoral programs.

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[1] In this paper, I use the term "completion rate" to mean the opposite of "attrition rate." That is, students either complete their degrees, leave without the degree, or remain enrolled.

The mathematics community has become concerned with small numbers of women pursuing higher education in mathematics. (National Research Council, 1992; Madison & Hart, 1990), but little is known about the reasons for women's departure from mathematics. Studies about the attrition of women from the sciences have implicated an array of causes, ranging from family responsibilities, which impact women more strongly than men (Nerad & Cerny, 1993; Lovitts, 1996; Sonnert & Holton, 1995), to epistemological concerns (Golde, 1996; Stage & Maple, 1996). Several authors have found that students who are more integrated into the academic and social communities of their departments are more likely to persist in graduate school (Girves & Wemmerus, 1988; Lovitts, 1996; Tinto, 1993). Students who are not well integrated into their departmental communities and cultures are more likely to leave graduate school for other reasons; for example, poorly integrated students are less likely to put up with financial hardship (Lovitts, 1996). Thus other reasons implicated in attrition actually mask an underlying issue of integration.

Women's relationships with faculty

Few authors have questioned how students *become* integrated. Girves and Wemmerus (1988) found that a faculty member "serves as a role model and becomes the primary socializing agent in the department. . . . It is the number of faculty members a student comes to know as professional colleagues that is associated with involvement in the doctoral program" which in turn is "directly related to doctoral degree progress" (p. 185).

Encouragement from mentors, in graduate school, college, and even high school, plays an important role in students' decisions to enroll and persist in graduate studies in mathematics (Carlson, 1999; Cooper, 2000; Hollenshead, Younce, & Wenzel, 1994; Manzo, 1994; National Research Council, 1992; Sonnert & Holton, 1995; Stage & Maple, 1996). Mentors within

graduate school can be particularly valuable in providing moral support and encouragement (Cooper, 2000; Hollenshead et al., 1994) and give advice on how to negotiate the system (Etzkowitz, Kemelgor, Neuschatz, & Uzzi, 1992). One common cause of attrition in the sciences is an incompatible relationship with advisors (Bair & Haworth, 1999; Girves & Wemmerus, 1988; Golde, 1996); this also has the effect of eroding students' reports of self-confidence (Berg & Ferber, 1983; Golde, 1996). In other disciplines, lack of both faculty mentoring and departmental advising has been associated with high attrition and long time to degree (Nerad & Cerny, 1993). Students who left graduate school have said that if their advisors or other faculty had been more supportive and sensitive, they might have been more inclined to stay (Lovitts, 1996).

Conversely, positive relationships with mentors can be important aspects of the student experience (Hollenshead et al., 1994). The overall norms and expectations of the departments and the quality of relationships with faculty are important factors in predicting degree progress (Girves & Wemmerus, 1988). Black women mathematics students in one program reported that, when they had doubts about continuing, their advisors encouraged them to stay and that the sense that their advisors cared kept them going (Manzo, 1994). Advisors can also help students learn to negotiate the politics of their departments and to learn the "rules of the game" (Cooper, 2000). In particular, if students have not been socialized to understand the political strategies necessary to survive in graduate school in science, advisors can help them learn these strategies (Etzkowitz et al., 1992).

Students who are treated as "junior colleagues" are more likely to stay enrolled in graduate school and complete degrees (Berg & Ferber, 1983; Girves & Wemmerus, 1988; Nerad & Cerny, 1993). Based on a survey of 459 graduate students who had been enrolled in 32

departments at one university in a seven year period, Berg and Ferber (1983) reported that graduate students who earned a doctorate (compared with those who enrolled in doctoral programs but did not earn a doctorate) were 3.4 times as likely (based on an odds ratio) to have reported being treated as a junior colleague by at least one male faculty member, and 4.8 times as likely to have come to know two or more male faculty members quite well. (Of course, students who left without completing the degree might have left before those relationships with faculty had the chance to develop.) Male degree recipients were significantly more likely than female degree recipients to have felt treated as a junior colleague by a male faculty member. (Relationships with female faculty could not be analyzed because few students in their sample had sufficient interaction with female faculty to give a sufficient sample size for analysis.) Conversely, students who feel they are treated as "adolescents" are less likely to complete degrees (Nerad & Cerny, 1993).

Negative interactions with faculty are pervasive for women in science. Sonnert and Holton (1995) documented forms of discrimination that women faced in finding mentors, ranging from professors who would not take on women students to mentors who just did not seem to tap into their professional networks as vigorously for their women students as they did for men. Women's opportunities were also limited by being excluded from the informal social networks of their laboratories or departments, being treated as "invisible," or otherwise having had their contributions marginalized (Becker, 1990; Etzkowitz et al., 1992; Sonnert & Holton, 1995; Stage & Maple, 1996).

Women students in the sciences and mathematics receive less mentoring from male faculty than do men students (Berg & Ferber, 1983; Etzkowitz et al., 1992; Hollenshead et al., 1994; Sonnert & Holton, 1995). There is a tendency for faculty to mentor same-sex students

(Berg & Ferber, 1983; Reskin, Koretz, & Francis, 1996). However, there are few women faculty in most SME disciplines. Berg and Ferber (1983) reported that in some departments at the University of Illinois at Urbana-Champaign, the percentage of students who were women was more than three times as great as the percentage of faculty who were women. This is currently true of mathematics in particular: in the Fall of 2000, 11% of full-time doctoral faculty were women and 31% of full-time graduate students were women (Loftsgaarden, Maxwell, & Priestly, 2001).

Thus relationships with department faculty, particularly advisors, can be hypothesized as a critical component of a graduate students' one important mechanism by which students become academically integrated. The small numbers of women faculty, the importance of positive mentoring relationships, the pervasiveness of negative mentoring relationships, and the tendency for faculty to mentor same-sex students all combine to pose a serious obstacle to integration for women in mathematics.

This paper uses interviews with six women doctoral students in one Mathematics Department, to look at the opportunities these women had to interact with faculty, and to begin to understand the relationships between women doctoral students and faculty as the students learn to become mathematicians.

Method

The Department

This study was conducted between the fall of 1999 and the fall of 2000, in the Mathematics Department at a large, public research university. The focus of the program is on the Ph.D., with a Master's awarded along the way to the doctorate.

In the fall of 2000, there were 51 tenured faculty members (49 men and 2 women) and 6 tenure track faculty members (5 men and 1 woman) in the Department (Department Secretary, personal communication, September, 2001). The Department enrolled 116 graduate students (103 full-time), of whom 26 (22%) were female. In the 1999-2000 academic year, 9 male and 2 female students received the Ph.D., and 22 male and 4 female students received Master's degrees (University website, 2001). The eleven students who received the Ph.D. in that year had been enrolled for between 4 and 12.5 years, with a median of 6.5 years (University website, 2001).

Of the 199 graduate students who entered the graduate program between 1983 and 1987, 98 (49%) completed the Ph.D. and 3 were still enrolled ten years later. Of the thirty-eight students who entered in the fall of 1990, 13 had received the Ph.D. and 2 were still enrolled 10 years later[2] (University website, 2001). That is, the attrition rate in this department is more than 50%.

Requirements in the mathematics doctoral program include coursework, exams, and research. Doctoral students are required to complete 18 graduate courses, which normally requires 3 years of full-time study. In addition to passing an exam in French, German, or Russian, students must pass written qualifying exams in two areas, out of the five that are offered. "These exams are given the week before the beginning of classes each semester. They

[2] Completion rates were not available for other cohorts.

are written, the time allowed for each is six hours, and they are based on our first year graduate curricula. For example, our first year curriculum in algebra should prepare one for the algebra exam. Qualifying exams may be taken as often as necessary" (Department website, 2001). The qualifying exams must both be passed by the beginning of a student's sixth semester, or she may no longer enroll in the program (although students can appeal for additional time). A student who does not pass the qualifying exams at the doctoral level might qualify for a master's degree instead. Once students have completed their coursework and qualifying exams, and are preparing to do research, they take an oral specialty exam in their intended area of research. Finally, students write up a "significant piece of original research" (Department website, 2001) as a dissertation.

The Interviews

This report is based on interviews that were part of a larger study, in which a total of 23 graduate students and 21 faculty members were interviewed. Of these, only the 6 female graduate students[3] are included here.

Participants were initially recruited through email messages sent to all the graduate students in the department. In addition, particular individuals were invited to participate based on recommendations from other participants. Because of the small numbers of women in the department, many women graduate students were individually invited. Participants were guaranteed confidentiality and the opportunity to review and comment on reports based on their interviews.

The six women had completed between one and more than six years of study at the time of their interviews. One of these women had left the program without the Ph.D., and another

[3] One other woman was excluded because the issues she chose to explore in her interview were not relevant to the current study.

decided to leave sometime after her first interview, but contacted me for a follow-up interview after she decided to leave. Two women were working on their dissertation research, one just beginning and the other close to finishing, and had considered leaving the program at some point in the past; one of them still thinks she may not complete the Ph.D. One first-year student and another who was working on her dissertation research had never considered leaving the program. In order to protect participants' identities, more specific demographic information cannot be provided.

The interviews were open conversations. In addition to asking for specific information and facts, Anderson and Jack (1991) call for the need to invite participants to discuss "the web of feelings, attitudes, and values that give meaning to activities and events" (p. 12) and to give them "the space and the permission to explore some of the deeper, more conflicted parts of their stories" (p. 13). These subjective and personal aspects of participants' stories were valuable sources of insight about their experiences within mathematics. However, encouraging participants to talk about these issues can be painful; some participants were discussing what they perceived to be failure (more than one confessed that they viewed their conversations with me as free therapy). To allow participants to avoid topics that were painful, while still leaving the interviews open to discussion of personal experiences and the meanings derived from them, each participant was given an outline of discussion topics several days before her scheduled interview, so that she had the opportunity to think about those topics, delete anything that she did not wish to discuss, and add topics that she considered relevant (after Burton, 1999b). Among these six women, none made deletions.

Interviews explored their initial experiences, interests, and goals in mathematics, reasons for choosing graduate study, expectations about their schooling, experiences in undergraduate

and graduate school, conceptions of mathematics, and decisions about continuing or leaving (see Appendix A). The interview outlines served as a starting point for the interviews, but each interview was different, covering those parts of participants' stories that they thought were relevant.

Interviews took place in a private office on campus, and ranged from 1to 3 hours, sometimes in 2 separate meetings. Interviews were audiotaped and transcribed. Participants were offered the opportunity to listen to the tapes of their interviews before giving me permission to use them.

Data analysis

The transcripts were analyzed inductively. After the interviews were transcribed, the transcripts were read again, while listening to the tapes, and initial codes were developed. The participants' stories were the real guide to coding the data, and codes were developed as necessary to reflect the themes that arose from the interviews, as they reflected on participants' descriptions of their relationships with faculty in the Department. As each transcript was re-read, new codes were developed and applied. Once the coding scheme reached a point where it seemed to capture the relevant parts of the participants' stories, all the interviews were re-coded.

As described above, the things the participants discussed differed according to their stories, and as a result, not all participants talked about the same topics. Also, there are only six participants, from which it is not meaningful to derive statistical information (for example, about how many people voiced a particular idea). Consequently, the text below presents a composite of all the participants' stories. Disagreements are presented if they were voiced.

In the text that follows, quotes are presented because they are particularly articulate or clear in expressing common themes discussed by the participants. Quotes were edited for

readability, removing stutters and distracting expressions such as "uh" and "you know", and references that might reveal participants' identities were obscured. Each participant is quoted between two and six times.

Results

Although these interviews covered a broad range of topics concerning these women's experiences in mathematics, their discussions of their interactions with faculty and other graduate students comprised almost 20 percent of their combined interview transcripts. All of the women interviewed described the limited or negative relationships they had with faculty. While students described different aspects of these relationships, there were several common themes among their comments. In particular they spoke about feeling invisible, needing guidance, wanting better teaching, lacking moral support, and wishing to be mentored.

Feeling invisible

The participants felt that first-year students needed more guidance and interaction with faculty. Many students felt overwhelmed during their first year, from the combination of the demands of coursework and for some, the adjustment to being in such a large department.

> I think a lot of people have a similar experience maybe to my first year where I was just thrown in with not that much guidance, not really understanding my classes, just sort of falling behind and not knowing how to get help. I wasn't real comfortable going to my professors. I think it's better when the professors of the first year classes actually reach out and talk to the students and I don't think that always happens. I think sometimes they just, they come in, they talk and they leave, and the students are just left with, not knowing what to do.

One woman, who came from a cultural background in which students were expected to conform to a formal code of behavior, enjoyed the informality and approachability of the professors in the Department.

> What I liked the most is the sense of freedom that you have . . . . I find it very refreshing that here nobody is watching you all the time to see how you behave and how you dress and how you act with other people.

Some women believe that the professors do not pay attention to graduate students until they prove themselves by passing their qualifying exams. One graduate student, who was finishing her dissertation at the time of the interview, described her frustration that she did not get any more attention after passing her exams than she did before.

> I had the impression early on that the faculty weren't paying all that much attention to me and I was assuming that it was sort of well, I haven't proved myself yet. I haven't passed my quals, I don't have an advisor. When I do those things that will change and it didn't, which was, which is still a source of frustration to me.

An advanced student described how accustomed she had become to this lack of attention. Later in her studies, when someone did show an interest in her work, she was surprised.

> I've very, very rarely had faculty members say, "So what are you working on? Tell me about your work." And when it has happened, it's happened in the last year or so. . . . After I gave a talk on Thursday one of the [faculty] who had been at the talk came up to me afterwards and in the context of talking about the talk, said "Yeah I've worked on some somewhat related things and maybe we should talk sometime." . . . And it's just that is a novel feeling to me and it shouldn't be, especially not when I've been around as long as I have.

Five of the six women felt that the professors were unfriendly, or even hostile. Several described the faculty as not caring.

> If I had to change the profession of mathematics, I would make people nicer. And I think that that would have lots of repercussions. . . . I think we would have more women in mathematics if people were nicer.

Each woman described the ways in which they sometimes felt awkward in a professional world with so few women.

> I had one female professor in my time here and it was so much easier to get interested because I could imagine myself being her. It's strange that I would just naturally get more interested in a class with a woman at the front and maybe it was because she was also a good lecturer and a lot of fun. The math department seemed so much like an old white guys' club, and I didn't really see that I had a place in the old white guys' club.

Needing guidance

In this mathematics department, each student is assigned an initial advisor at the beginning of her first year who usually remains in that role until the student passes qualifying exams and finds a research advisor. These women found this system ineffective, and rarely spoke with or got useful advice from their advisors.

> I spoke to him maybe twice about advising. I think from year to year he didn't remember that I was his advisee and he would be a little surprised when I'd come in with the sheet of paper that he had to sign for when I took my classes. . . . He must have had a million of us little advisees and he obviously took little or no interest in the direction of my academic career, and really he had no reason to. . . . It's not that he didn't like me, it's just that he didn't necessarily care. . . . Had I had an advisor who I felt like I could ask, "Do you think this is the right course?" "How should I be proceeding about this, that, the

> other thing?" If I had gotten some advice that I felt like this person was advising me and not just advising a first-year grad student who comes here with a vague interest in [subject] that I would have gotten something out of that.

As a result, they did not receive the advising they felt they needed or expected, saying that they suffered from the lack of advising, which might have helped them make better decisions about courses to take and could have given them a more clear idea of what to expect. Three women felt that because of the bad advice, or lack of advice, they received when they started the program, they ended up in courses that were inappropriate choices for them or did not take courses that would have contributed to their mathematical training in important ways.

> He would give us these hard homework problems and I would go in to ask him about it. . . . Eventually I'd go and ask him stuff and then he'd say something like, "You really need to work on your analysis more. You should really take real analysis next year." . . . I went in to ask him a question about this homework. Instead of explaining to me something, he would correct what I had done wrong with my education which is really what *he* had done wrong, because I had wanted to take that course and he told me not to. That was infuriating. . . . It made me feel badly that I didn't have the analysis background. And Professor Y did the same thing. He said that [course] was an unwritten prerequisite for [course] but no one told us that. I wanted to take that course but I was discouraged from it, and then they tell you this all later and it made me feel ashamed, like I didn't have the background, therefore I was bad. Like I was an insufficient student.

Wanting better teaching

Although the graduate students complimented some lecturers for their clarity or organization, or for making the material interesting, their complaints about the teaching of the courses included the lack of interaction between the instructor and the students, difficulty discerning the important information, incomprehensible lectures, non-English textbooks, and the lack of motivation or connections among mathematical ideas and the mathematical "big picture".

> He'd come in and he would just race through the stuff on the board and we would furiously copy down what he was doing and it just seemed like just streams and streams of words, just signifying nothing. Then we'd have like a month of this with no homework, nothing really, really no indication of what on earth was going on, not much in terms of why we were doing what we were doing or where this was going. Just, ok here's a lemma, here's the proof, here's another lemma, here's the proof, here's a theorem. Very little motivation, and I think I didn't see the whole big picture.

Most of the women graduate students complained about the lack of feedback mechanisms in their courses. In many of the first-year courses in this doctoral program, professors do not give students feedback on their work; in some classes, work was not even assigned or collected.

> The algebra course we had I think 2 assignments over the whole semester, unless I'm mis-remembering and there was only one, and that's not enough feedback. Even in the topology course where we probably had 4 or 5 homework assignments over the course of the semester, there was still not a whole lot of feedback from those particular assignments. The most useful feedback was . . . after assignments were due, there would be a point where we'd say alright we're going to take today and just talk about these problems that were in the homework assignment, and that was a useful form of feedback.

> Although a more individual, "this is where you there's a flaw in your argument" or "this is where you've overlooked something" would have been useful too.

They complained that they either could not ask questions, or felt that they were rebuffed or chastised when they did.

> I go and ask a question like "I don't understand this part of the notes. When you go from here to here and there's really no explanation and I'd be told, "there's a very good book on this in the library." It got to the point where it's becoming offensive. . . . Three was one time I went to go see Professor X in office hours and then he was on the phone. He said, "Can you come back in ten minutes?" I said, "Sure." And I came back in 10 minutes and he was gone. Sometimes I've sent an email saying, "you only have office hours once a week and I didn't understand something and I can't come to office hours today. Can I set up a time to meet you?" and he wouldn't respond for 5 days and then he'd say, "Why don't you come to my office hours?" It kind of got to the point that it was so evident that this guy didn't want office hours or to teach his class that it was just offensive.

In contrast, this student described being able to get helpful answers to her questions.

> In one of my courses in my second semester we had homework and we were encouraged to go and discuss with the professor the problems and the homeworks, so I used to go and discuss with him quite a lot.

Some of these women described boring classes in which the excitement for mathematics was missing, with little explanation.

> [Course] wasn't a terribly pleasant experience during the course because I had learned a bit of [subject area] before but this person's approach was a little different. That's alright but he didn't really explain very much to us, so during most of the time during this course I was sort of a little lost. . . . He would go over and he would do theorems and things like that but I think it might have been my fault too because he had the sort of voice that tended to make me not pay attention to it. So after a while I would be mechanically writing down things that he wrote on the board without really registering what they meant.

These women had all come into the program with a passion for some aspect of mathematics, which helped motivate them to work very hard to understand mathematical concepts and ideas.

> I find it intriguing. It's very beautiful. I love working on it, I really do. And it's crazy because there are other things I love. . . . It's just fascinating to me. It's the only subject that ever really made me like want to go out and read more. . . . Being able to understand it and being able to do it, for me it was a huge like motivation, knowing that if I put some more effort in, to whatever class, I can almost understand it but I'm missing this part. All I have to do is figure out this one thing and then I'll understand all about this theory, and I knew that I could do that part. I could talk to my professor, you know, I could read the book again, I could go through the notes again. There are a lot of ways to figure out that.

Unfortunately, the education they received in the department left them with a "bad taste" in their mouths, and some described having lost their love of mathematics.

> I had taken a lot of this material before and I'd sit there in horror. He was slaughtering this stuff. This was stuff I thought I wanted to study [for] the rest of my life and he's sitting there just slaughtering this beautiful math. It was horrible. I just wanted to start screaming in the middle of class, "No! You're not talking about it right! Make it clear!"

Lacking moral support and encouragement

The moral support and encouragement provided to graduate students by mentors have been found to be particularly valuable (Cooper, 2000; Hollenshead et al., 1994). The women in this study said that when they did receive such support, it made a big difference to them.

> I think the main reason that I'm still here is having gotten support from him and it's really sort of more emotional support and moral support at the one critical time. . . . The time I thought most about leaving, my advisor was there and basically said no, you shouldn't do this. You are close to finishing. I know, I do believe you can do this.

Most of the women, however, had complaints about the lack of moral support and encouragement they received from their instructors and advisors.

> There was virtually no encouragement from the professors to start. . . . Well one professor I know of said to one person I know, it's possibly apocryphal, they didn't really care about us until we passed the quals because until we passed the quals we hadn't proved ourselves and so they weren't even going to bother thinking about us. And that was what it felt like my first year, like we were nothing. They didn't care at all. . . . It would be a lot better if they could reach out more . . . maybe take an interest in what students are doing . . . . It's hard for me to get used to being just average for the group I'm in. I guess going from a big fish in a little pond to the whole ocean is sort of painful,

> and I'm not sure there's anything that math grad school here could do about that. Well, I mean they could be more encouraging, right? They could tell you sometimes that you did well, maybe.

Wishing to be mentored

All of these women complained of ways in which they did not received mentoring in mathematical thinking. They described wanting to know more about how their professors think about mathematics, how they approach solving problems, or how their work fits into the broader mathematical landscape.

> I have learned to do mathematics enough to work on my thesis but I often don't feel like I'm doing things as efficiently as I could be . . . . How do you go from seeing, "yup this looks like a pattern alright" to actually proving it? . . . I don't feel I've learned enough about how to research productively and how to tell when I'm tackling a problem that's just going to be too complicated or going about it in a way that's going to get too unwieldy. I haven't yet really figured out how to decide when I can trust my intuition to follow something and when that's likely to lead me astray. . . . Researchers could explain or demonstrate how their own thought processes work and how do you go from saying, "Gosh, one should be able to calculate the [mathematical term] to saying, "I'm going to use this technique, and I'm going to look for this kind of evidence"?

Even the women who were close to finishing their dissertations noted that they had not had any mentors in graduate school.

> There were a number of people that were encouraging and said "You're doing very well" or whatever but no one influence stands out.

Q: So no particular mentor?

A: No, no.

One woman said she came to graduate school expecting to be treated like a junior colleague, and was disappointed that that was not what she found.

> Graduate school should really be more of the mathematical apprenticeship than it is now in the sense that as graduate students we should be learning to be mathematicians and we should be learning to interact as mathematicians, and I don't feel like I get much encouragement. That involves a lot of interactions between people, between faculty members and graduate students. My biggest frustration is that there isn't enough of that and I don't feel like the department as a whole in some sense cares.

One benefit of being treated as a junior colleague is that it can help a student develop "tacit knowledge", the unspoken cultural rules and informal knowledge of the discipline that graduate students need to master, and which they develop through contact with more experienced researchers (Gerholm, 1990). If students have limited interactions with faculty, then they will have limited opportunities to develop tacit knowledge about the discipline. One advanced graduate student enjoyed support she received from a new faculty member, who helped her develop some tacit knowledge about mathematics.

> What he is doing is he's telling all the graduate students, "Yes you should go to the colloquium." And then . . . a couple days after he runs a session where he goes over some of the concepts that were discussed there. . . . I was also thinking that, "Boy I wish someone had been doing this 5 years ago." I would have gotten so much out of this. Another thing he's doing in conjunction with that is what he's referring to as a "tricks of

the trade" workshop, things that you have to know as a working professional mathematician that you never really get taught explicitly but somehow you need to know.

Discussion

The six women participants described relationships with their professors that might be characterized by "benign neglect", in which there was little interaction either in or out of class. Here I will present two different frameworks for interpreting these results.

Legitimate peripheral participation in a community of practice

The underlying process of the interactions between doctoral students and faculty can be conceptualized using the model of legitimate peripheral participation (Lave & Wenger, 1991), in which students participate in authentic ways at the periphery of legitimate mathematical practice which, in time, moves students to more central participation in the community of practice. "The important point concerning learning is one of access to practice as resource for learning, rather than to instruction" (p. 85). "Old-timers" (i.e. the faculty or the more advanced graduate students) set the stage for the activity of the newcomers. The activity of the community provides a "curriculum" for those students who have legitimate access to that activity; that is, students learn through their participation in the activity of the academic community. "Participation in the cultural practice in which any knowledge exists is an epistemological principle of learning. The social structure of this practice, its power relations, and its conditions for legitimacy define possibilities for learning (i.e. for legitimate peripheral participation)" (p. 98). This process involves a cycle of social reproduction in which, as newcomers move to more central participation in the community of practice, they will eventually displace the old-timers—a process that Lave and Wenger call the "continuity-displacement contradiction."

Lave and Wenger (1991) warn that learners need "access to peripherality" in addition to legitimate participation, and point to "the crucial character of broad, and broadly legitimate,

peripheral participation in a community of practice as central for increasing understanding and identity" (p. 85). In order for students to become central participants in the practice of mathematicians, they need access to all the means of membership. If doctoral students have restricted access to the community of practice, then their ability to become integrated is inhibited.

> Apprentices [can be] put to work in ways that deny them access to activities in the arenas of mature practice. Gaining legitimacy may be so difficult that some fail to learn until considerable time has passed. . . . Gaining legitimacy is also a problem when masters prevent learning by acting in effect as pedagogical authoritarians, viewing apprentices as novices who 'should be instructed' rather than as peripheral participants in a community engaged in its own reproduction. (Lave & Wenger, 1991, p. 76)

The women interviewed for this paper had limited opportunities to participate in legitimate ways in mathematical practices. They described distant relationships with faculty, in which the faculty have little to do with the students outside of class; in class, they provide few glimpses of how mathematicians think about mathematics. In their classes, without assignments and feedback on their work, these women described the ways in which the faculty do not help them develop their abilities to think mathematically.

Mathematics is a highly specialized discipline and many graduate students have few peers with whom to collaborate (National Research Council, 1992). In order for students to become central participants in the practice of mathematicians, they need access to all the means of membership in that community. That means that they need to interact with the "old timers" (Lave and Wenger, 1991)—the faculty—in order to learn the practice of the mathematical community. Although these women reported working with other students regularly on

coursework, later in their studies, when they do research, they are left without access to other members of the community—faculty and graduate students—with whom to interact as they learn the more central mathematical practice.

Given that the faculty in this department is mostly male, and the tendency of faculty to mentor same-sex students (Berg & Ferber, 1983; Reskin et al., 1996), it is little surprise that these women felt they had no mentors. Burton (1999a) interviewed 70 practicing mathematicians in the U.K., and found that none of them had had a female advisor, yet many of the 35 women she interviewed were advising graduate students; she concluded that there may be reason to expect that women will have increased opportunities to have women as advisors.

Caring

Noddings (1992) proposes a model of education based on the notion of caring: for self, for strangers and distant others, for animals, plants and the earth, for the human-made world, and for ideas; it is the last of these that will be of interest here. Noddings argues that, in order to engage students in school in productive ways, and in order to help them develop into caring, moral adults, educators need to engage those students in caring relations within schools.

Noddings (1992) identifies four components of education from a perspective of caring: modeling, dialog, practice, and confirmation. In effective mathematics teaching, then, teachers would do four things. They would model their care for mathematics, and for their students. They would engage students in dialog—in meaningful, mutual, open-ended discussion. They would provide students with opportunities to practice caring about mathematics; this is not intended to merely be rote drill in mathematical computation, but engagement with the habits of mind often referred to as "mathematical thinking." And they would provide confirmation to their students—positive, affirming feedback that stems from a trusting, established relationship.

The mathematics professors in this department did none of these things. Although the women in this study initially cared a great deal for the world of ideas represented by mathematics, they described classes devoid of enthusiasm, which failed to communicate the "big picture" or motivation for mathematical ideas. Likewise, they perceived that the faculty did not care about them as students. The faculty did not model caring, either for mathematics or for these women.

Students had few opportunities to interact with the faculty about mathematical ideas; most of their coursework consisted of listening to professors lecture, and the students reported not even being able to ask questions. They wanted more and better advising, and reported few mentoring relationships. The only opportunities they had to engage in dialog about mathematics were with other graduate students.

These women complained about courses with few assignments that often were not graded, and although they often tried to find their own problems to solve, they wished for meaningful feedback on their work so that they could develop their mathematical thinking. They described not knowing how their professors think about mathematics, and what they thought they might learn from seeing just that. The faculty did not set up situations in which students could practice caring about mathematics.

Given the lack of interaction between faculty and graduate students, there was little mention of positive feedback of any kind. The women described a lack of encouragement, and little meaningful feedback on their work. The faculty did little to confirm these developing mathematicians.

What does this mean for women in mathematics?

Women graduate students in science and mathematics have been stereotyped as less capable and uncompetitive, and as a result they may not be taken seriously by faculty (Becker, 1990; Etzkowitz et al., 1992; Stage & Maple, 1996). Women learn, starting from a young age, to look for interaction, attention, and reinforcement, rather than to be autonomous and independent learners (Etzkowitz et al., 1992; Fennema & Peterson, 1985). It seems likely, then, that women would be more likely to flourish in an educational setting based on an ethic of care (Noddings, 1992). Indeed, the women whose experiences are reported here expressed a need for more care in many ways—along all four dimensions of Noddings (1992) framework.

However, in a disciplinary culture like that found in mathematics, work is expected to be individualistic and independent. Female graduate students' preferred styles of interaction may be different than those expected by male faculty, whose work is most decidedly not based on care; those behaviors may be misinterpreted as inferior, rather than different.

> In [one] department a female academic model based on inter-personal relationships, affiliation and nurturance had become accepted as legitimate and had even become the departmental norm. This was in strong contrast to another research site where the expression by women of a need for these characteristics in the laboratory environment was derided as a desire for dependence and emotionality by the adherents of the patriarchal system that was in place. (Etzkowitz et al., 1992, p.174)

This lack of care had the effect on at least two women of leading them to leave the program without completing the Ph.D. Two other women described their deliberations about leaving, but it was an overt act of care on the part of a faculty member that led them to stay.

The importance of students' interactions with faculty to their integration in the department was argued earlier. Building caring relations between faculty and graduate students, and between graduate students and mathematics, can be important avenues to participation in the community of practice of mathematicians, for women and for men. Conversely, their participation in that community can enhance their care for mathematics. However, if women feel that they do not fit in mathematics, or if there are other obstacles in their path to becoming integrated, then this presents a particular challenge for women.

The mathematics community has been concerned with the state of doctoral education, including the small numbers of women and minorities completing the Ph.D., and the decreasing proportion of Ph.D.s awarded in the U.S. to U.S. citizens.

> Many doctoral students are not prepared to meet undergraduate teaching needs, establish productive research careers, or apply what they have learned in business and industry. This inadequate preparation, continuing high attrition, and the declining interest of domestic students, the inadequate interest of women students, and the near-absent interest of students from underrepresented minorities in doctoral study are problems that transcend the current difficult job market. (National Research Council, 1992, p. 1)

These concerns may not be as unrelated as they may appear at first glance. In order to open the discipline of mathematics to a broader range of students, and to engage them in mathematics in meaningful ways, students need the means to participate in the practices of mathematicians in genuine ways, in the context of relations based on care among teachers, students, and the discipline of mathematics.

Appendix

Interview Outlines

I. Graduate Students

The questions below are intended to give a direction to our discussion, but are not requirements for how it will develop. Feel free to delete anything from the list that you do not wish to discuss, and to add anything else that you feel might be relevant.

About your mathematical autobiography:
When did you first become interested in math? How did that interest develop?
What interested you about it? Have your interests changed?
Why do you like it?
What do you think mathematics is? Have these ideas changed?
Have there been any people who have been influential to you in mathematics?
What experiences have you had with mathematics, either in or out of school?
How did those experiences affect you?
Do you feel successful in mathematics?
Why did you decide to come to graduate school? Why at [the University]?

About your experiences in graduate school:
Which aspects of graduate school met your expectations? Which didn't? Why?
How did you like your classes?
How did they compare with your interests in math?
How do you learn math best?
What about other activities within the math department-how did they relate to your interests?
What have you enjoyed most about your experience here? What have you enjoyed least?
What have your relationships with professors been like? With other graduate students?
How would you describe your professors' beliefs about mathematics? How do they compare with your own?
What does it take to succeed in graduate school?

If you are staying in the program:
Did you ever consider leaving? Why?
Which factors have been the most helpful in helping you to stay in the program, and to succeed to this point?

If you left the program, plan to leave, or are thinking of leaving without finishing:
At what point in your program were you when left or will you be when you leave?
When did you first start having doubts?
Why did you leave, will you leave, or are you thinking of leaving?
If you could change anything about the math department or program here to make it a better experience for you, what would you change?
Do you have any second thoughts?
What will you do/are you doing after graduate school?

Some other general questions:
Do you think gender, sexuality, race, ethnicity, nationality, age, handicap, or any other factors outside of your mathematical ability have had any impact on your experiences within mathematics? How?
Have these factors had any effect on the experiences of other graduate students?
What factors do you think influence the persistence or attrition of graduate students?
How would you design a math program if you really wanted to turn students on to math?

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